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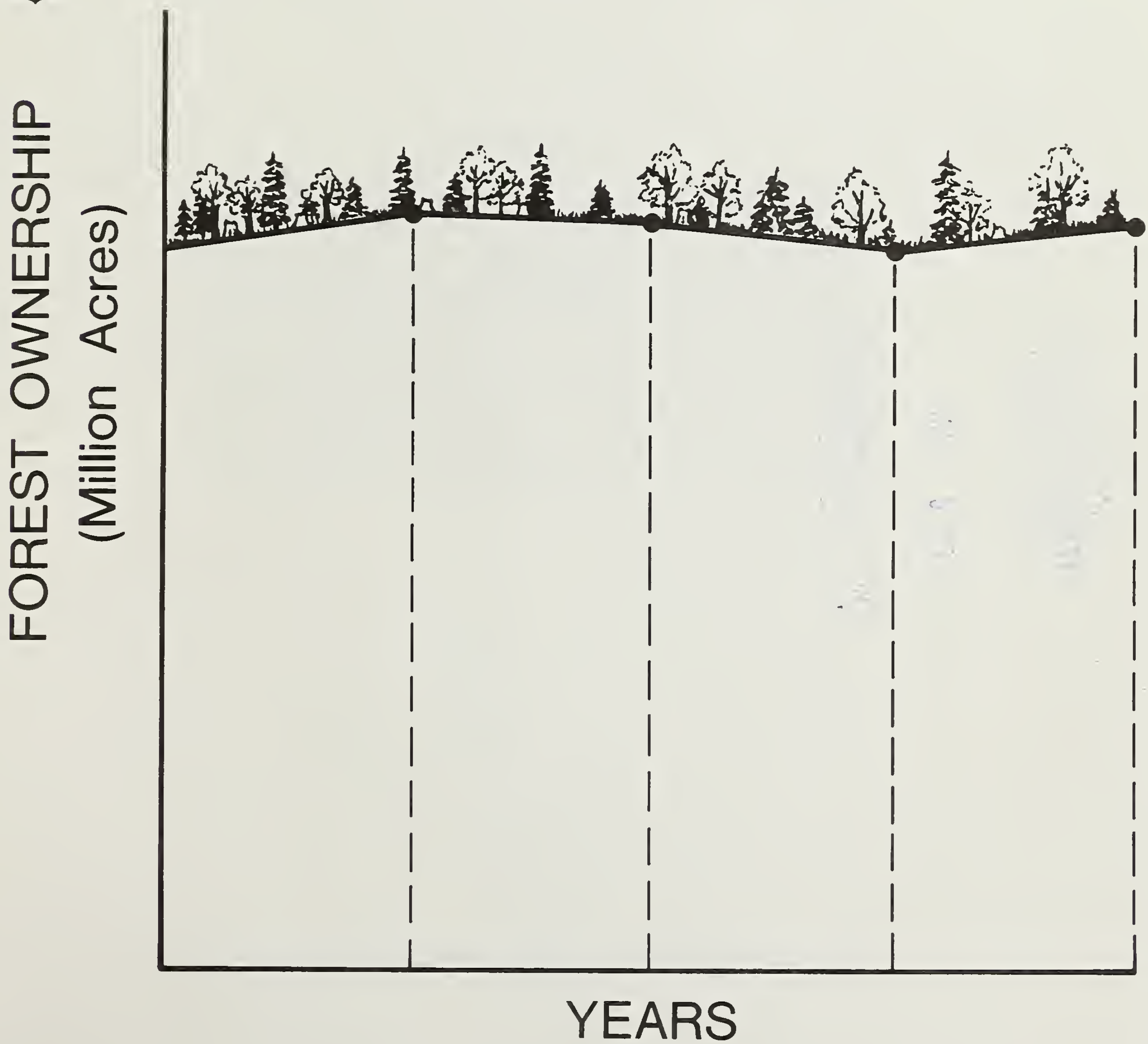
Modeling Acreage Changes in Forest Ownerships and Cover Types in the Southeast

Ralph J. Alig



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Ralph J. Alig, Research Forester
Rocky Mountain Forest and Range Experiment Station[1]

Abstract

A system based on economic criteria projects changes in acreages of six major land ownerships/uses by physiographic region in the Southeast, including three private forest ownership classes. Acreage changes for five major forest types, on each of the three forest ownerships, are projected using transition rates among forest types associated with the application of certain management practices. Changes in forest acreage, projected by decade to the year 2040, indicate a continued drop in farm forest acreage and natural pine acreage.

[1]Headquarters is in Fort Collins, in cooperation with Colorado State University.

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Management Implications

Prospective changes in acreages for major land uses/ownerships and forest types are important considerations in the formulation of renewable resource policy. Competition among rural land uses is expected to be particularly intense over the next several decades in the Southeast because several sectors of the economy may expand production there. Changes in ownership distribution and in acreages of forest types can lead to substantial impacts on a variety of natural resources.

Population, personal income, and land commodity incomes are significant variables in land ownership/use equations. Changes in population and personal income levels have contributed to a decline in farm forest acreage and a corresponding increase in miscellaneous private forest acreage.

Projections with the system of land owner/use equations developed in this paper indicate a continued drop in farm forest acreage. Miscellaneous private forest acreage is projected to continue to increase. Projections of acreage changes for the five major forest types by ownership in each physiographic region indicate a substantial reduction in natural pine acreage. The probabilities of area changes in forest types were estimated from forest survey remeasurement data, and depend on application of certain management practices.

Because of the influence of external factors (e.g., population) on forest acreage trends, improved coordination of land use modeling for all sectors of the economy is needed. Also, forest acreage modeling needs to be integrated in an interregional framework with that for forest type transition, timber inventory projection, and harvest estimation.

Introduction

Projected acreage changes for land uses, ownerships, and forest types play an important role in both the analytical and policy aspects in the periodic assessments of long-range forest and range market trends required by the Forest and Rangeland Renewable Resources Planning Act of 1974. For example, acreage shifts influence both short-term timber supply and long-term timber investment behavior, and consequently, the supply of lumber and plywood. When acreage is removed from the timberland base, part of the associated inventory is marketed and contributes to current harvest (i.e., stumpage supply). However, loss of these acres reduces the aggregate growth potential of the timber resource. Supply may be lower than it would have been if these acres had been retained, depending in part on changes in timber investment in response to higher stumpage prices because of acreage reductions. The higher stumpage prices can drive up resource costs in a region, resulting in shifts in regional production of forest products (Alig et al. 1983). In addition, acreage shifts involving forestland impact both economic and ecological systems, including other natural resources (e.g., wildlife habitat) (Alig 1983).

Rural land use competition is expected to be particularly intense during the next several decades in the Southeast. Different sectors of the economy, including crop agriculture, pasture and range based agriculture, and forestry, may expand production there. In recent studies, more than 11 million acres of forest in the Southeast (15% of the timberland base) were identified as having high or medium potential for conversion to cropland (Dideriksen et al. 1977). The South had the largest population increase of all U.S. regions between 1950 and 1980; therefore, impacts of continued population expansion on the rural land base area are also important.

Forest acreage projections in previous timber supply assessments were based on opinions of regional experts, such as Wall's (1981) projection of commercial forest land acreage by region in the 1980 RPA Assessment (USDA Forest Service 1982). To estimate future commercial forest land, Wall subtracted the number of acres estimated to be withdrawn for uses of perceived higher economic (e.g., agriculture) or social value (e.g., wilderness) from the potential commercial forest land base. These projections then were used in estimating stumpage supply in the Timber Assessment Market Model (TAMM). Adams and Haynes (1980) recognized that the amount of forested acreage is not independent of the timber price projections made in TAMM, but concluded that the decisions involving the many possible uses of land are too complex for direct inclusion in TAMM.

One weakness of the expert opinion approach has been that the questions addressed are not empirically linked to objective and independently verifiable criteria (Sackman 1974). Sackman (1974) concluded that the technique is essentially unreliable and scientifically unvalidated. Armstrong (1978) was also critical of this type of approach.

Burnham (1973) used a Markov model to simulate land use changes over time in estimating future United States cropland availability. The finite Markov chain process employed probabilities of land use shifts based on movements between use groups over a historical time period. MacDonald et al. (1979) also applied a Markov chain model to project bottomland hardwood acreages in the Lower Mississippi alluvial plain to 1995.

Another weakness of expert opinion or Markov type approaches is that they do not allow a systematic analysis of the dynamic relationships among major economic variables and changes in forest acreage and ownership distribution. Projecting changes based on past land use trends does not identify the causes of these changes, therefore, the processes underlying land use shifts can not be quantified. The Markovian probabilities are aggregate measures of all influences acting on land use shifts. In addition, implicit assumptions, such as the stationarity assumption for land use transitions, may be unrealistic because of changing economic conditions.

When previous approaches are used, the effects of alternative policies on future area patterns can be examined only by means of very rough parametric shifts in land allocations; however, the relationship of these changes to the alternative policies of interest may not be clear. These approaches generally suggest that future land use patterns will be continuations of historic trends, despite the fact that different future economic and social conditions may be expected.

Other analytical approaches include the soil expectation value framework used by Vaux (1973) and Hyde (1980). These economic efficiency models can estimate long-term steady-state outcomes, but lack mechanisms for modeling the dynamics of changes in forest acreages. They also do not consider conversion of forestland to major competing uses (e.g., agriculture). Georgia Supply (GASPLY) (Montgomery et al. 1975, Robinson et al. 1978), another static economic model, does model conversions between forest and agriculture uses; however, it also lacks mechanisms for modeling adjustments over time that are needed for empirical testing.

The Center for Agricultural and Rural Development (CARD) model, developed to project changes in agricultural land use (English et al. 1982), projects conversion from forestland to cropland. The CARD model has estimated the conversion using the normative concept of least cost production to meet specified consumption levels. However, it has not considered land shifts to forestry (i.e., assumes returns to forestry are not positive). Because land use models, in general, have not projected all major land uses simultaneously, total land base constraints have not been explicitly addressed.

No regional projection models of changes in forest acreage have been developed that reflect historical relationships among ownership distribution, relative land product price trends, and other important land use determinants. One reason is that it is difficult to construct adequate time series of data for historical land use patterns. Classification criteria used to define timberland differ among major data sources. The most reliable series of forest acreage data consists of periodic estimates for survey regions within a state (Alig 1984a).

The limited success in projecting changes in land use may partially be the result of several combined characteristics of the market, owners, and analyses themselves. Imperfect market information, uncertainty, "noneconomic" goals, and lack of technical skills are examples of possible confounding market and owner-related factors. Analyzing the impact of changing government programs (e.g., USDA ERS 1983) on crop acreage has been a central problem in agricultural supply analysis since World War II (Houck et al. 1976). Government programs were often altered to reflect changing short-run views of economic conditions. An important analytical shortcoming may also be the inability to fully account for relevant returns, especially nonmonetary benefits, and costs accruing to a landowner from alternative land uses. This includes the influences of nontimber outputs on timberland management decisions, which have not been extensively tested (Binkley 1981).

The study reported here was designed to provide a modeling framework for projecting long-term changes in the acreages of the major land uses, forest ownerships, and forest types. A related paper (Alig 1984b) presents details on the estimation of the econometric equations that are used as a basis for the long-term projections of the acreages changes. This paper focuses on the projection methodology and the data used to support the projections.

Projection Methodology for Land Uses and Ownerships

Econometric equations that use economic, demographic, and other important variables were incorporated into a model, the Southeast Area Model (SAM), that projects acreages of the major land uses and forest ownerships in the Southeast. An overall schematic of the SAM system is presented in the Appendix. The development of the theory and estimation of the econometric models were described by Alig (1984b). The specified relationships for the six land owner/use classes are presented in table 1. The equations are based on land rent theory that suggests that the fraction of the land base devoted to a land use will be positively related to rent for that use relative to rents from competing uses.

The land use equations were estimated simultaneously using a seemingly unrelated regression approach, including the use of pooled cross-sectional and time series data. Data for the dependent variables, which represent the proportion of the land base occupied by a land use/owner, were collected by the USDA Forest Service, Forest Inventory and Analysis (FIA) unit at Asheville, N.C. Land use acreages for a state are estimated periodically in such surveys, with the entire Southeast covered approximately in 10-year cycles.

The estimated econometric equations are presented in tables 2, 3, and 4 for the Coastal Plain, Piedmont, and Mountain regions, respectively. The econometric results vary somewhat by region, but suggest that demographics and macroeconomics have important influences on land use changes in each physiographic region. The least satisfactory equations in terms of goodness of fit are the forest industry and pasture/range equations for the Coastal Plain.

Table 1.—Specified relationships for the six land owner/use classes.[1]

$$
\begin{aligned}
C &= a_1 + b_1 Y_{F/C} + c_1 Y_{C/P} + d_1 UPOP + e_1 RPOP + f_1 Y_T \\
P &= a_2 + b_2 Y_{F/P} + c_2 Y_{C/P} + d_2 UPOP + e_2 RPOP + f_2 Y_T \\
U &= a_3 + \qquad d_3 UPOP + e_3 RPOP + f_3 Y_T \\
FA &= a_4 + b_4 Y_{F/C} + c_4 Y_{F/P} + d_4 UPOP + e_4 RPOP + f_4 Y_T + g_4 G_s \\
FI &= a_5 + b_5 R + c_5 Y_s \quad d_5 UPOP + e_5 RPOP + f_5 Y_T + h_5 S \\
MP &= a_6 + b_6 I + d_6 UPOP + e_6 RPOP + f_6 Y_T + g_6 G_o + h_6 S
\end{aligned}
$$

Where:

C	=	Percentage of survey unit's land base occupied by crops
P	=	Percentage of survey unit's land base occupied by pasture/range
U	=	Percentage of survey unit's land base occupied by urban and other related uses
FA	=	Percentage of survey unit's land base occupied by farm forestland
FI	=	Percentage of survey unit's land base occupied by forest industry forestland
MP	=	Percentage of survey unit's land base occupied by miscellaneous private forestland
$a_i\, b_i\, c_i\, d_i\, e_i\, f_i\, g_i h_i$	=	Parameters to be estimated (i = 1,...,6)
$Y_{F/C}$	=	Ratio of expected forestry to crop income per acre
$Y_{C/P}$	=	Ratio of expected crop to pasture/range income per acre
$Y_{F/P}$	=	Ratio of expected forestry to pasture/range income per acre
$UPOP$	=	Urban population
$RPOP$	=	Rural population
Y_T	=	Real per capita income
S	=	Expected southern pine stumpage income
G_s	=	Tree planting expenditures under the Soil Bank program
G_o	=	Tree planting expenditures under other government programs
R	=	Proportion of forest industry softwood removals to total removals
Y_s	=	Southern pine products income
I	=	Inflation rate

[1]*Dummy variables to distinguish major geographic areas are not shown, but would be included in each equation.*

Table 2.—SURE econometric estimation results for the Coastal Plain Region.[1]

Variables	Crop	Pasture/ Range	Urban/ Other	Farm forest	Forest industry	Misc. private
Intercept	19.02*	9.27*	11.46*	37.30*	25.45*	5.12*
	(7.37)	(3.64)	(8.28)	(4.53)	(6.00)	(2.50)
Timber income				.69		
				(.25)		
Beef income		−1.37				
		(−1.73)				
Personal income	−1.11		6.28*	−19.61*		8.94*
	(−.45)		(4.59)	(−6.28)		(3.43)
Urban population	−5.37*		1.16*	−3.98*		2.00*
	(−6.02)		(2.02)	(−4.63)		(2.71)
Rural population					−3.49*	
					(−2.22)	
Wood products income					11.15*	
					(1.74)	
Industry removals (%)					6.69*	
					(2.92)	
Government forestry programs						1.91*
						(3.53)
Georgia dummy			−5.40*		−5.71*	
			(−4.37)		(−2.92)	
North Carolina dummy		−3.48*	−2.18			
		(−5.68)	(−1.77)			
South Carolina dummy		−2.78*			−7.33*	
		(−4.76)			(−4.03)	
Virginia dummy		−3.22*	−2.54	11.34*		
		(−4.00)	(−1.82)	(4.52)		
MAE[2]	4.89	1.30	2.62	3.68	5.05	2.83
Mean of dependent variable	22.58	3.25	13.59	28.44	15.72	16.43
Adjusted R^2	.54	.28	.53	.82	.32	.75
Sample size, n = 36						

[1]*Number in parentheses below coefficients are t-statistics.*
[2]*Mean absolute error.*
**Significantly different from zero at the 0.05 level.*

Table 3.—SURE econometric estimation results for the Piedmont Region.[1]

Variables	Crop	Pasture/ Range	Urban/ Other	Farm forest	Forest industry	Misc. private
Intercept	17.99*	5.28	4.87*	25.87*	6.66*	15.37*
	(5.76)	(1.09)	(4.13)	(3.52)	(10.95)	(4.17)
Beef income		1.27				
		(.87)				
Crop income	8.12*					
	(2.56)					
Timber income				9.11*		
				(4.45)		
Personal income	– 15.96*		6.04*	– 23.15*		23.02*
	(– 7.87)		(5.31)	(– 6.59)		(6.97)
Rural population	– 15.42*					21.91*
	(– 4.24)					(7.22)
Urban population			1.25*	– 6.34*	– 1.87*	
			(2.15)	(– 7.62)	(– 3.36)	
Inflation rate				– 7.94*	6.31*	
				(– 3.43)	(7.44)	
Government forestry programs						1.07*
						(1.75)
Georgia dummy				– 5.76*		
				(– 3.43)		
North Carolina dummy	18.78*				– 5.05*	– 21.74*
	(5.51)				(– 5.28)	(– 5.71)
South Carolina dummy		– 2.53*	3.33*	– 14.64*		
		(– 2.05)	(4.25)	(– 7.68)		
Virginia dummy	– 8.17*	4.75*			– 3.35*	
	(– 3.48)	(4.04)			(– 4.20)	
MAE[2]	2.45	2.55	1.97	3.49	1.71	4.34
Mean of dependent variable	19.45	10.18	9.96	33.15	6.69	20.57
Adjusted R^2	.76	.31	.73	.84	.60	.73
Sample size, n = 21						

Table 4.—SURE econometric estimation results for the Mountains Region.[1]

Variables	Crop	Pasture/ Range	Urban/ Other	Farm forest	Forest industry	Misc. private
Intercept	19.22*	23.51*	67.55*	– 13.84	2.20	– 27.72
	(18.64)	(5.79)	(17.46)	(– 1.11)	(.77)	(– 1.80)
Crop income	5.57*					
	(2.03)					
Beef income		– 7.44*				
		(– 5.74)				
Timber income				10.84*		1.89
				(3.01)		(.41)
Personal income	– 12.46*			– 17.55*	– 2.26	22.71*
	(– 8.88)			(– 4.82)	(– 1.45)	(4.37)
Urban population		– 4.29*	21.25*	– 11.40*	– 2.42*	– 9.94*
		(– 3.17)	(11.21)	(– 3.18)	(– 2.05)	(– 2.86)
Inflation rate					3.91*	
					(3.70)	
Government forestry programs						2.29*
						(4.06)
North Carolina dummy	– 4.30*		1.82			
	(– 5.66)		(1.89)			
Virginia dummy		13.13*	– 6.61*		– 3.71*	– 3.09
		(15.85)	(– 5.65)		(– 4.74)	(– 1.73)
MAE[2]	.82	1.15	1.91	3.45	1.24	3.32
Mean of dependent variable	9.70	14.71	24.50	24.98	3.59	22.51
Adjusted R^2	.89	.94	.87	.74	.56	.70
Sample size, n = 13						

[1]*Number in parentheses below coefficients are t-statistics.*
[2]*Mean absolute error.*
**Significantly different from zero at the 0.05 level.*

The models project use/ownership acreages by decade to the year 2040 (fig. 1), which corresponds with the current RPA planning horizon for which other variables of interest (e.g., timber removals) are projected in related studies. The major land uses are projected simultaneously, with a total land base limit imposed so that projections can not exceed a state's land area (Alig 1984a). Initial discrepancies between actual total land area and the area projections are apportioned by the model according to weights that correspond to the relative percentage of the land base occupied by a use/ownership.

Projections of land use and ownership shifts require a variety of assumptions regarding prospective trends for a diverse set of variables that influence land base changes. Highly accurate predictions for important variables, such as long-run population and economic growth, are not possible. Instead, reasonable assumptions are made about future levels of these variables that are based on (1) historical trends, (2) developments that affect those trends, and (3) expectations regarding future changes.

Projections of population through the year 2000 by state, prepared by the Bureau of the Census (USDC Bureau of the Census 1983), were used for the baseline case. Population projections for years beyond 2000 were based on extrapolation of the Bureau of Census projections and expert opinion. Projected total population estimates were apportioned into rural and urban components, using the most recent Census proportions, by physiographic region within a state. Projected population estimates were distributed within the survey units in a state according to the most recent census estimates of distribution within a state. Total population is projected to increase in Florida by more than 145% over the projection period, and by more than 50% in several of the other southeastern states (fig. 2).

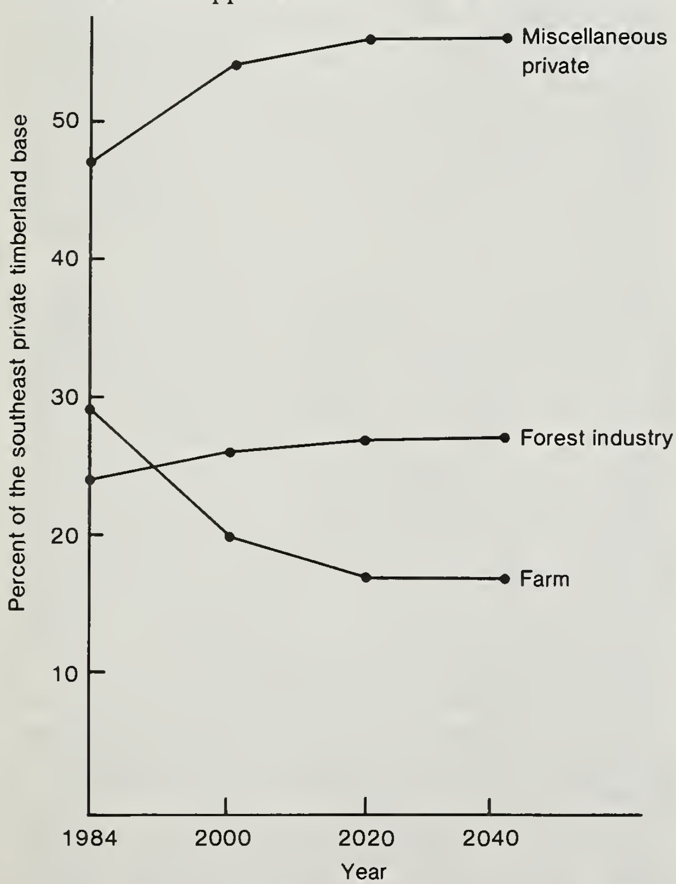

Figure 1. Projections of the distribution of private forest area by ownership in the Southeast.

Personal income projections were based on the national rate of change embodied in Gross National Product (GNP) projections to the year 2030 developed by the USDA Forest Service for RPA Assessment analyses.[2] The medium level of GNP rate of growth was used, which is based partly upon "medium" level projections of population and associated projections of labor force and productivity. The projected rate of economic growth results in a tripling of real per capita income by the end of the projection period (fig. 3). Historically, real per capita income has expanded approximately 2.5 times in the South since 1948 (USDC Office of Business Economics 1949). The fairly constant relationship between the levels of personal income and GNP for the past 50 years was assumed to continue through the projection period.

Projections of income per acre for crop and pasture/range uses were based on agricultural price and productivity projections to the year 2030 in the Soil Conservation Service's RCA analysis (USDA 1981). The RCA price projections are based on the CARD/RCA modeling (English et al. 1982), and the ERS Report 435 (Lu et al. 1978) provided the guidance for the 1980 RCA assumptions regarding agricultural productivity. Constant real future crop prices were projected, with an annual productivity growth of 1.1% projected to the year 2000 and 0.9% annually thereafter. Constant real prices and no changes for productivity were assumed in projecting livestock incomes.

Timber incomes were projected based on an assumption of constant productivity and southern pine stumpage prices projected to the year 2030 by the Timber Assessment Market Model (Adams and Haynes 1980). Stumpage prices were adjusted by physiographic region and state using results from Hunter (1982). Projections of timber product prices and industry removal percentages also were based on TAMM projections. The TAMM projections, in turn, were based partly upon earlier area projections formulated from expert opinion (Wall 1981). However, the simultaneous determination each decade of area changes and changes in related economic parameters, such as timber prices, was outside the scope of this study.

Projected inflation rates were based on Wharton's baseline long-term forecast of price indices (Wharton 1983). Wharton's projections up to the year 2002 were extrapolated to the year 2040. The annual percentage changes projected for the price indexes ranged from approximately 2% to 5% over the projection period.

Current funding levels for government cost-share programs for tree planting were projected using annual

[2]Personal communication with Adrian Haught, USDA Forest Service; RPA Staff; Washington, D.C. (November 1983).

rates of real increase equal to 1%. Historically, real rates of funding increases have been greater than 3% annually (over some decades); but the projected values reflect slower annual increases because of anticipated reductions in such domestic programs.

Projected Area Changes

The projected area changes by forest ownership in figure 1 for the Southeast are similar across the three physiographic regions—Coastal Plain, Piedmont, and Mountains; only the regional projections are shown here. The largest acreage changes in the farm forest (5.7-million-acre reduction) and miscellaneous private (2.7-million-acre increase) classes are projected for the Coastal Plain. The largest acreage change for forest industry, a 1.4-million-acre increase, is projected for the Piedmont region.

The largest projected changes in Southeast forest acreage are for the farmer and miscellaneous private owner classes. Farm acreage is projected to continue to drop, with the projected 2040 value 45% lower than the 1984 acreage. In contrast, miscellaneous private acreage is projected to increase 11% by 2040. These divergent trends are similar to historical patterns. Most of the acreage changes in these two ownerships occur by the year 2000.

Projection Methodology for Forest Type Area

Long-range trends in projected natural resource supplies are sensitive to the forest type transition estimates used as input in timber inventory projection models

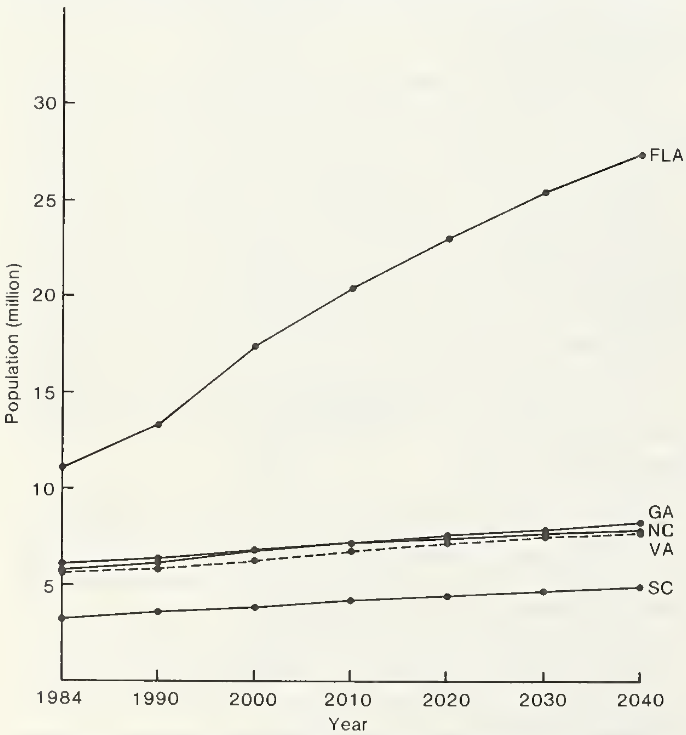

Figure 2. Projected population levels, by state for 1984 to 2040.

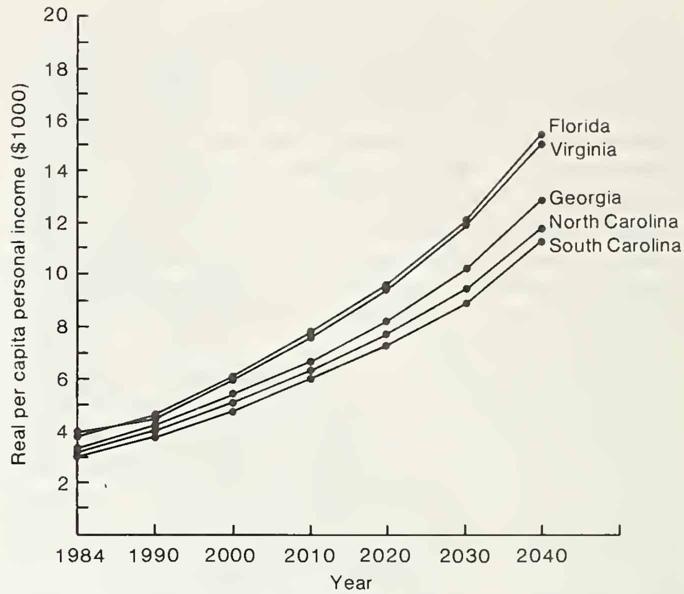

Figure 3. Projected levels of per capita personal income, by state for 1984 to 2040.

(Brooks 1984). The model used in this study to project forest type acreages is a preliminary attempt to address this question systematically. Research designed to improve upon this approach is described in a related study plan.[3]

Timber inventory projection models used in regional timber supply appraisals have based their simulation of future timberland management on three different approaches or assumptions (Alig et al. 1984): extrapolation of management implicit in measured stand growth rates, e.g., TRAS model (Alig et al. 1982), analysis of positive investment behavior, e.g., SPATS (Brooks 1984), and analysis of treatment opportunities, e.g., TRIM.[4] The SAM model can project forest type acreages to the year 2040 under any of these three assumptions regarding the application of land management practices.

The first option was used for the projections of forest type acreages in this study because of the availability of associated data. It simulates forest type transitions for three different categories of land management practices for which the USDA FIA survey group collects periodic data: (1) no management or disturbance, (2) final harvest, and (3) other miscellaneous management or disturbances. The simulations are based on historical rates of transition among major forest types. Three sets of input by owner and physiographic region are required: (1) original state or distribution of forest types, (2) probability of application of the three land management classes, and (3) conditional transition probability that a forest type will shift to a particular forest type in response to receiving one of the three types of manage-

[3]*Alig, Ralph J., James G. Wyant, and Herbert A. Knight. 1983b. Study plan: Analysis of forest type transition in the Southeast. USDA Forest Service Rocky Mountain Forest and Range Experiment Station. 47 p. Fort Collins, Colo.*

[4]*Tedder, P. L., J. P. Gourley, and R. N. Lamont. 1983. The timber resource inventory model (TRIM): A timber inventory projection model for national timber supply projections and policy analysis. Contract report to the USDA Forest Service, O-FRER staff. 155 p. Corvallis, Oreg.*

ment. The conditional forest type transition probabilities are multiplied by the management probabilities and the initial area[5] in a particular forest type on an ownership. The resultant area estimates are summed by owner, forest type, and physiographic region. The equation form is:

$$A_{i,j,t+1} = \sum_{j=1}^{5} \{ \sum_{k=1}^{3} \{ P(D_{k_{i,j,t}}) \times P(FT_{i,j,t+1}/D_{k_{i,j,t}}) \times A_{i,j,t} \} \}$$

Where:

$A_{i,j,t,}$ = Forest area in private ownership i and forest type j in decade t (i = 1,2,3; j = 1,...,5; t = 1...,7).

$P(D_{k_{i,j,t}})$ = Probability of a primary disturbance of type k on ownership i and forest type j in decade t (k = 1,2,3).

$P(FT_{i,j,t+1}/D_{k_{i,j,t}})$ = Probability of a unit area of timberland on ownership j in decade t + 1 being in forest type j in response to a primary disturbance of type k on that unit area in decade t.

The use of dynamic transition probabilities (i.e., a unique transition probability matrix for each time period) was precluded by the unavailability of data for developing appropriate adjustment mechanisms. The impact on forest type transitions of changes in management practices, such as increased timber investment levels or acceleration of private harvesting, can be simulated in sensitivity analyses by modifying the probability of management or the transition probabilities associated with certain management practices (or both). Incorporation of more detailed information on timber management practices is currently also precluded by lack of data.

The future distribution of forest types is projected in figure 4, using the transition probabilities for forest type by ownership given in table 5. These projections assume a similar future mix of land management practices will continue. An important land management concern is the lack of active forest regeneration efforts after harvest, in many cases on non-industrial private lands. Many acres shifted from pine to hardwood types, primarily after harvests that were not followed by pine regeneration efforts (Boyce and Knight 1979, 1980). As table 5 indicated, pine forests gradually convert to oak-pine, and then to hardwoods, if natural successional processes are not changed.

The probabilities for forest type transition in response to a type of land management, used in the projection of forest type distribution, are aggregate measures of all influences acting on forest development. These influences include human disturbances and natural succession forces (Alig and Wyant 1985). The investment behavior embodied in the forest type projections is not sensitive to changing relative prices for timber products. Modeling of timber investment activity has not kept pace with other recent advances in aggregate timber supply analysis (Alig et al. 1984).

[5]*Area adjustments by forest type for diversions from and reversions to the timberland base are estimated based on recent survey data.*

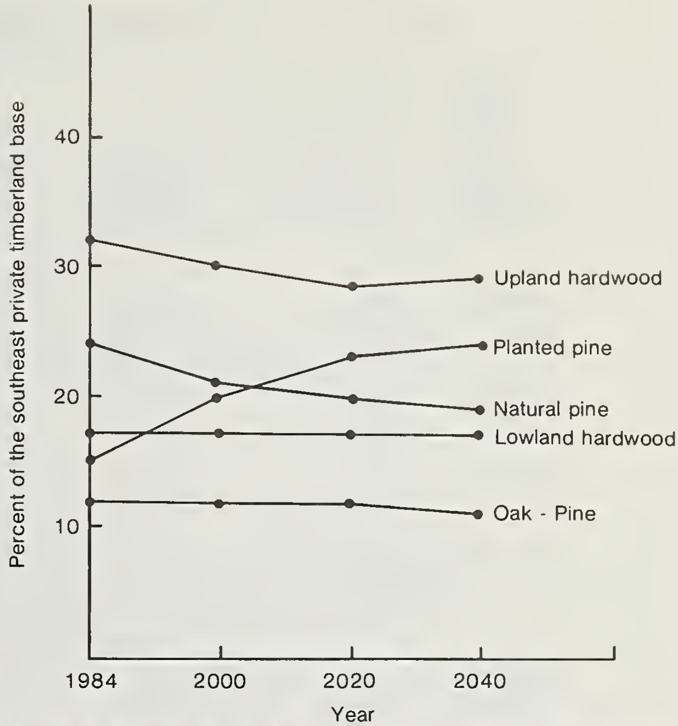

Figure 4. Projections of the distribution of private forest area by cover type in the Southeast.

Projected Area Changes

Historical rates of forest type transition by physiographic region were estimated from the most recent periodic FIA surveys (approximately one a decade) for Florida, Georgia, and South Carolina (table 5). Consistent transition information is only available for the most recent FIA surveys in this area. Therefore, the same transition rates were applied across all states, with distinct transition probabilities applied by physiographic region.

The projections of the distribution of private forest area by type in figure 4 indicate that the largest changes will occur in the southern pine types. Natural pine acreage is projected to decrease by more than 25% by year 2040. Planted pine acreage is projected to increase by more than 55% over the same period, mostly on forest industry lands. This shift in pine types results in little net change in southern pine acreage over the projection period.

Other Modeling Considerations

Constraints based on historical rates of transition were applied to the projections to preclude illogical or unreasonable trends in projected land use/ownership percentages. Region-wide land use trends are not quickly changed or reversed because of the slowly changing

Table 5.—Forest type transitions (in percentages) between the most recent two FIA surveys for Florida, Georgia, and South Carolina.

Forest type during earlier survey (Source)	Primary disturbance/ management	Probability of disturbance/ management	Probability of destination by forest type at latest survey				
			Natural southern pine	Planted southern pine	Oak-pine	Upland hardwood	Lowland hardwood
			Farm Ownerships				
Natural southern pine	None	29.4	90.8	0.0	6.7	2.0	0.5
	Harvest	23.8	39.1	9.3	17.5	25.6	8.5
	Miscellaneous	46.8	85.8	1.2	8.8	3.2	1.0
Planted southern pine	None	17.6	4.6	80.7	9.0	2.5	3.1
	Harvest	18.5	41.5	12.8	4.1	38.7	2.9
	Miscellaneous	63.9	5.8	91.1	1.1	1.2	0.7
Oak-pine	None	45.6	27.9	0.6	51.6	14.5	5.4
	Harvest	18.5	7.5	2.8	21.6	48.2	19.9
	Miscellaneous	35.9	23.6	2.7	43.1	24.4	6.2
Hardwood	None	54.9	1.7	0.0	8.2	40.7	49.4
	Harvest	13.9	3.3	1.8	4.3	42.9	47.7
	Miscellaneous	31.2	4.7	0.8	11.0	47.2	36.3
			Miscellaneous Private Ownerships				
Natural southern pine	None	29.4	92.9	0.5	4.7	1.7	0.2
	Harvest	43.8	34.2	18.6	19.9	22.5	4.7
	Miscellaneous	26.8	85.0	3.1	7.3	3.3	1.3
Planted southern pine	None	33.7	4.1	93.2	2.7	0.0	0.0
	Harvest	12.2	31.4	29.8	10.5	24.8	3.5
	Miscellaneous	54.1	4.2	92.9	2.1	0.8	0.0
Oak-pine	None	45.1	30.8	1.8	45.2	15.2	7.0
	Harvest	30.1	8.7	11.1	23.1	43.9	13.2
	Miscellaneous	24.8	28.1	2.8	36.8	28.0	4.3
Hardwood	None	58.3	1.6	0.1	8.6	43.3	46.4
	Harvest	17.6	3.4	8.1	13.4	43.7	31.4
	Miscellaneous	24.1	3.7	3.6	8.0	46.9	37.8
			Forest Industry Ownerships				
Natural southern pine	None	33.7	92.9	0.7	4.8	0.0	1.6
	Harvest	24.2	16.4	61.2	7.7	9.0	5.7
	Miscellaneous	42.1	72.8	16.6	6.0	3.0	1.6
Planted southern pine	None	29.2	1.8	94.6	2.1	0.8	0.7
	Harvest	16.9	13.7	57.7	9.5	16.9	2.2
	Miscellaneous	53.9	1.4	95.8	2.0	0.8	0.0
Oak-pine	None	47.7	21.6	6.7	46.1	12.0	13.6
	Harvest	17.7	5.6	25.5	17.4	34.2	17.3
	Miscellaneous	34.6	31.3	32.1	14.5	13.0	9.1
Hardwood	None	61.8	2.6	0.1	6.1	21.0	70.1
	Harvest	10.1	1.1	25.1	4.4	29.0	40.4
	Miscellaneous	28.1	4.7	25.1	7.4	19.2	43.6

macro forces at work. To reflect this, two types of constraints were imposed: (1) limits on percentage changes by decade for each land use/ownership, and (2) limits on the absolute percentage of land that may be occupied by a particular land use/ownership. These constraints were applied at the physiographic region level within each state, for each of the six major land uses/ ownerships.

Limits on changes in land use percentages by decade (table 6) were constructed from the author's analysis of historical trends and expert opinion.[6] Rapid changes in land use percentages are unlikely because of the capital limitations of owners, the inertial nature of land management, and the slowly changing trends in relative land product incomes.

The current extent of land use also was considered in setting the percentage limits. For example, forests generally have covered 60% to 80% of the Southeast; changes over a decade typically have been in the range of 2% to 15%. Parallel changes in pasture/range land use were 0.5% to 5% (pasture/range typically only occupies 2% to 15% of the land in a survey unit).

Limits on the upper and lower percentage ranges for each land use are presented in table 7. These also are

[6]*Personal communication with Herb Knight, USDA Forest Service, Southeastern Forest Experiment Station, Asheville, N.C. (November 1983).*

Table 6.—Bounds on rates of change (percentage of total land base) by decade in land use percentages.[1]

Physiographic region Land use/owner	Positive rates of change					Negative rates of change				
	Fla.	Ga.	N.C.	S.C.	Va.	Fla.	Ga.	N.C.	S.C.	Va.
Coastal Plain										
Farm forest	0.032	0.030	0.038	0.031	0.034	0.032	0.042	0.045	0.051	0.047
Forest industry forest	0.014	0.019	0.016	0.016	0.016	0.026	0.010	0.014	0.019	0.017
Miscellaneous private forest	0.027	0.038	0.038	0.038	0.038	0.031	0.033	0.036	0.030	0.031
Cropland	0.028	0.037	0.037	0.029	0.034	0.026	0.031	0.029	0.035	0.031
Pasture/range	0.026	0.028	0.024	0.019	0.018	0.026	0.026	0.021	0.019	0.018
Urban/other	0.029	0.026	0.029	0.026	0.026	0.013	0.013	0.013	0.013	0.013
Piedmont										
Farm forest	[1]	0.021	0.037	0.033	0.040	[1]	0.050	0.040	0.050	0.046
Forest industry forest	[1]	0.023	0.015	0.023	0.021	[1]	0.011	0.013	0.021	0.019
Miscellaneous private forest	[1]	0.042	0.041	0.046	0.040	[1]	0.026	0.030	0.036	0.034
Cropland	[1]	0.041	0.041	0.036	0.031	[1]	0.031	0.036	0.036	0.031
Pasture/range	[1]	0.028	0.030	0.038	0.031	[1]	0.030	0.026	0.028	0.030
Urban/other	[1]	0.030	0.038	0.032	0.027	[1]	0.013	0.017	0.016	0.016
Mountains										
Farm forest	[1]	0.023	0.039	[1]	0.036	[1]	0.048	0.043	[1]	0.043
Forest industry forest	[1]	0.020	0.019	[1]	0.019	[1]	0.017	0.026	[1]	0.013
Miscellaneous private forest	[1]	0.046	0.045	[1]	0.041	[1]	0.016	0.034	[1]	0.031
Cropland	[1]	0.044	0.038	[1]	0.032	[1]	0.030	0.033	[1]	0.032
Pasture/range	[1]	0.028	0.027	[1]	0.029	[1]	0.028	0.028	[1]	0.030
Urban/other	[1]	0.032	0.033	[1]	0.027	[1]	0.011	0.011	[1]	0.111

[1]*Indicates a nonexistent state-physiographic region combination.*

based on expert opinion and analysis of historical low and high percentages for each land use, by physiographic region within a state. All land use percentages were constrained to fall between 0% and 55%.

Use of these constraints relied heavily upon expert opinion in this first round of land use/ownership modeling, because the constraints reflected factors that have not been extensively researched. Sensitivity of the land use/ownerships projections to the imposition of the constraints on rates of change was tested by preparing a set of projections without the constraints. The projected acreages in the year 2040 for the two sets of projections differ by less than 10%, with the biggest changes in the crop and miscellaneous private forest categories. Therefore, while the constraints influenced the projections, they did not seriously affect projected results.

Other modeling considerations include the inability, because of data limitations, to differentiate among the several major types of owners combined in the diverse miscellaneous private class. In particular, corporate owners are an increasingly large part of this class. Also, existing data did not allow the leasing of nonindustrial lands to be handled meaningfully in this study.

Model Validation

Validation refers to evaluating a model's structure and behavior in comparison to the structure and behavior of the referent system to increase confidence in the ability of the model to provide reliable information or insights for analyzing policy issues. Validation addresses several questions pertaining to model application and utility: (1) whether the model is appropriate for its intended use(s); (2) whether the benefits of improving performance exceed the costs; (3) whether the model contributes to making "better" decisions; and (4) possibly how well the model performs compared to alternative models.[7] The general objective of the SAM research is to develop a model that can project long-term acreage changes for major land uses, ownerships, and forest types to support forest resources planning in RPA Assessments. The primary application is for the long-range evaluation of the impacts of a broad range of external forces (e.g., population growth) on land base shifts. The ultimate concern is with policy decision making and the value of related policy analyses, which is directly related to the accuracy of estimates of long-term changes on the land base. Mills and Flowers (1983) stress that an evaluation of the sensitivity of model outcomes to variations in input data and to variations in the completeness of model specification should be an integral part of any model building. If the model output is relatively unaffected by model refinement, those incremental costs are not justified.

[7]*McCarl, Bruce A., and A. Gene Nelson. 1983. Model validation: An overview with some emphasis on risk models. Paper presented at the annual meeting of Regional Research Project S-180, San Antonio, Texas, March 28-30, 1983.*

Table 7.—Upper and lower limits (percentage of the total land base) on occupation of the land base by major uses/ownerships.[1]

Physiographic region Land use/owner	Lower limits Fla.	Ga.	N.C.	S.C.	Va.	Upper limits Fla.	Ga.	N.C.	S.C.	Va.
Coastal Plain										
Farm forest	0.022	0.085	0.165	0.102	0.123	0.193	0.323	0.360	0.290	0.327
Forest industry forest	0.175	0.072	0.087	0.098	0.100	0.410	0.300	0.210	0.210	0.208
Miscellaneous private forest	0.165	0.095	0.115	0.131	0.124	0.417	0.295	0.340	0.325	0.319
Cropland	0.058	0.125	0.188	0.165	0.141	0.217	0.361	0.368	0.295	0.267
Pasture/range	0.023	0.021	0.011	0.015	0.016	0.182	0.168	0.085	0.086	0.076
Urban/other	0.092	0.035	0.081	0.111	0.080	0.285	0.207	0.210	0.223	0.234
Piedmont										
Farm forest	[1]	0.065	0.175	0.115	0.165	[1]	0.196	0.387	0.296	0.389
Forest industry forest	[1]	0.060	0.011	0.070	0.052	[1]	0.240	0.092	0.167	0.168
Miscellaneous private forest	[1]	0.195	0.145	0.187	0.147	[1]	0.520	0.347	0.382	0.358
Cropland	[1]	0.074	0.138	0.078	0.086	[1]	0.283	0.385	0.356	0.237
Pasture/range	[1]	0.056	0.031	0.038	0.078	[1]	0.185	0.136	0.178	0.219
Urban/other	[1]	0.059	0.098	0.091	0.091	[1]	0.220	0.206	0.242	0.205
Mountains										
Farm forest	[1]	0.050	0.095	[1]	0.084	[1]	0.190	0.281	[1]	0.285
Forest industry forest	[1]	0.038	0.015	[1]	0.011	[1]	0.140	0.105	[1]	0.096
Miscellaneous private forest	[1]	0.210	0.220	[1]	0.055	[1]	0.492	0.435	[1]	0.398
Cropland	[1]	0.048	0.036	[1]	0.039	[1]	0.187	0.169	[1]	0.186
Pasture/range	[1]	0.043	0.041	[1]	0.126	[1]	0.177	0.179	[1]	0.274
Urban/other	[1]	0.190	0.200	[1]	0.160	[1]	0.376	0.402	[1]	0.386

[1]*Indicates a nonexistent state-physiographic region combination.*

Validation exercises can vary widely, including comparison of model solution vectors with corresponding real world vectors. In a practical sense, validation is very difficult for long-range forestry-based models where outcome sets for comparative purposes are not available. Therefore, a frequently used approach to validation involves evaluating the goodness of fit of model simulations over historical periods (Kost 1980). Ideally, to evaluate predictive ability, several observations would be excluded from use in parameter estimation and used to evaluate the forecasting ability of the model. However, because of the limited number of available observations, it was necessary to use all the observations in this study for parameter estimation. Survey estimates of land use acreages were only made periodically for each state, which greatly limits validation that is based on data sets that are separate from those used in estimation.

Because unexpected future events cannot all be provided for in a model, researchers have proposed using model predictions for historical periods to examine a model's predictive ability (Salathe et al. 1982). Measures of a model's ability to replicate history include the traditional method of evaluating the accuracy of such models by the use of summary statistics, such as t-scores, F-tests, and R^2's statistics (Larson 1983). These statistics represent the type of information generally provided in articles dealing with evaluation of model performance. Other validation statistics also have been proposed to determine the predictive adequacy of econometric models (Pindyck and Rubinfeld 1976). The most widely used include: the percent root-mean-square (RMS) error, Theil's inequality (U) statistics, and the correlation coefficient. The root-mean-square (RMS) percentage error is defined as:

$$\text{Percent RMS} = \sqrt{\frac{1}{N} \sum_{n=1}^{N} \left(\frac{\hat{Y}_{it} - Y_{it}}{Y_{it}}\right)^2}$$

Theil's inequality (U) statistic is defined as:

$$U = \frac{\sqrt{\frac{1}{N} \sum_{n=1}^{N} \left(\frac{\hat{Y}_{it} - Y_{it}}{Y_{it}}\right)^2}}{\sqrt{\frac{1}{N} \sum_{n=1}^{N} \hat{Y}_{it}^2} + \sqrt{\frac{1}{N} \sum_{n=1}^{N} Y_{it}^2}}$$

The coefficient of multiple determination (R^2) is defined as:

$$R^2 = \frac{\sum_{n=1}^{N} (\hat{Y}_{it} - \bar{Y})^2}{\sum_{n=1}^{N} (Y_{it} - \bar{Y})^2}$$

Where

N = Number of sample observations for the dependent variable

$\hat{Y}_{it}$ = Simulated level of the dependent variable for survey unit i at time period t

Y_{it} = Actual level of the dependent variable for survey unit i at time period t

$\bar{Y}$ = Mean level of the dependent variable over the survey units and time periods.

Performance of the Land Use Acreage Model

The SAM system was validated over the 1947–1983 period for which historical data was available. Model errors for the historical period stemmed from the inability of the SAM equations to exactly predict area changes for land uses/ownerships in any particular year. Table 8 presents the validation statistics computed for the land use equations in the SAM system. Overall, the equations appear to predict with reasonable accuracy. The farm/forest equations had the highest explanatory power of all equations in the Coastal Plain and Piedmont regions. In contrast, the pasture/range and forest industry equations had noticeably lower associated measures of predictive performance for those regions.

The goodness of fit of the forest acreage equations was similar across regions, except for the forest industry equations. The highest R^2's and lowest prediction errors for the nonforest land uses were associated with the Mountain equations. The R^2's for the Piedmont equations also were generally high, except for the pasture/range equation. For the Coastal Plain, the equations for forest industry and pasture/range were the least satisfactory. Alig (1984a) provided a detailed discussion of these differences and possible causes.

For example purposes, the predicted and actual values over the sample period for the farm forest ownership is plotted in figure 5 by physiographic region. The survey cycles represented on the horizontal axis refer to FIA remeasurement periods. The surveys for the five states were added at those four points in time to provide a basis for evaluating the historical simulations.

The predicted trends for the farm forest ownership approximated the actual trends closely. The predicted forest industry trends did not follow the actual trends as closely, especially in the Piedmont and Coastal Plain. The miscellaneous private forest equations closely tracked the actual trends, except for underestimating the Survey Cycle 3 level in the Piedmont region. This deviation is the converse of the overestimated Piedmont dip for the farm ownership during the same period.

Sensitivity analyses also were conducted to investigate the robustness of the SAM modeling system. As discussed by Alig (1984a), the long-term projections of acreage changes were not very sensitive to 30% changes (by decade) in assumptions pertaining to the major independent variables (e.g., urban population). The 30% change was selected to represent a realistic margin of error for the projections of major independent variables. Three factors may have contributed to the in-

Table 8.—Validation statistics for the SAM system, 1947–1983.

Physiographic region Land use/owner	Percent root-mean square (RMS) error	Theil U_2 statistic	Multiple correlation coefficient (R^2)
Coastal Plain			
Crop	35.2	.12	.57
Pasture/range	64.7	.22	.36
Urban/other	34.1	.11	.59
Farm forest	21.4	.08	.84
Forest industry forest	87.3	.18	.42
Misc. private forest	159.9	.10	.77
Piedmont			
Crop	17.2	.07	.82
Pasture/range	30.0	.14	.41
Urban/other	27.9	.11	.77
Farm forest	17.0	.06	.89
Forest industry forest	53.3	.14	.68
Misc. private forest	71.1	.11	.79
Mountains			
Crop	10.4	.05	.92
Pasture/range	12.6	.05	.96
Urban/other	9.8	.04	.91
Farm forest	25.1	.08	.80
Forest industry forest	86.8	.16	.71
Misc. private forest	31.4	.08	.83

sensitivity of the projections to input parameters: (1) the logarithmic functional forms of the land use relationships, (2) the small size of the incremental change relative to projected levels of change for the major independent variables, and (3) the constraints placed on the land use changes to preclude changes that would deviate significantly from historical trends.

The interaction of the three factors make it difficult to determine the relative importance of each. However, the latter two factors are thought to have the largest influences. For example, one of the major independent variables, population, is projected to increase by more than 145% in Florida and by more than 50% in several other states over the projection period. These are large changes relative to the incremental 30% increase. In addition, upper level constraints on rates of land use change in some cases further lessen the impact of increasing population levels. However, as discussed earlier, the constraints are not overriding in their effect, but may contribute to the influence of the other factors.

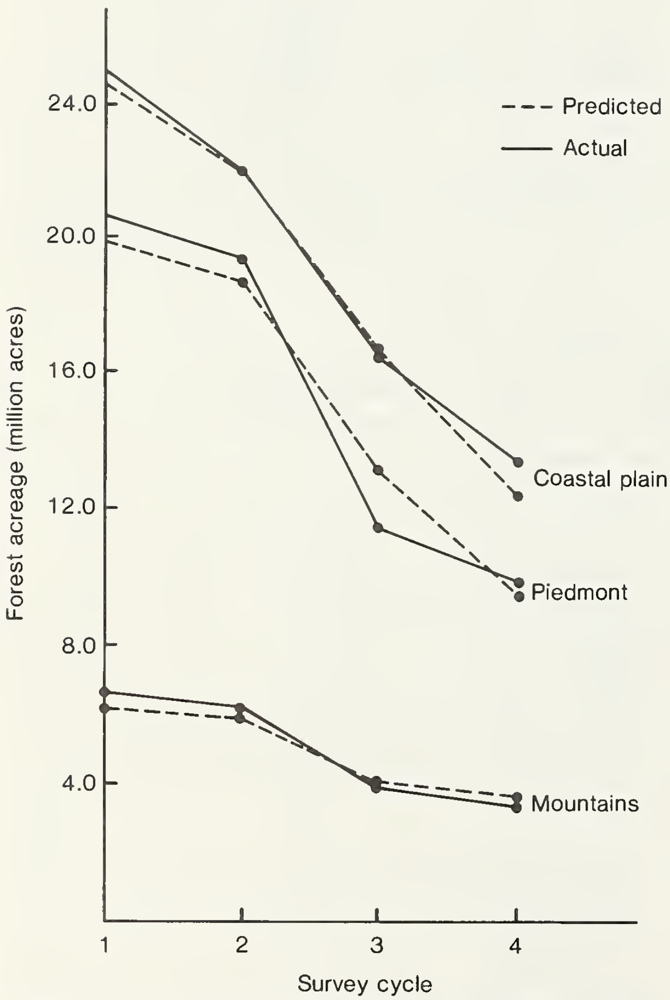

Figure 5. Actual and predicted changes in farm forest acreage by physiographic region.

Conclusions

Changes in population and personal income levels have contributed to a decline in farm forest acreage and a corresponding increase in miscellaneous private forest acreage. Projected changes in the acreages of forest ownerships with the SAM model, which is based on econometric equations, indicate a continued drop in farm forest acreage and an increase in miscellaneous private forest acreage. Projections of acreage changes for the five major forest types by ownership in each physiographic region point to a substantial reduction in natural pine acreage. These projections are based on application of certain management practices.

Research is needed to improve the efficiency of linking forest acreage estimation more strongly to forest type transition, timber inventory projection, harvest, and investment modeling in aggregate timber supply studies (Alig et al. 1984). Forest acreage projections support timber inventory projection modeling, and as a result the modeling of regional stumpage prices, number of acres devoted to forestry, and the timber management schemes are interrelated. This suggests that a simultaneous solution network or feedback loops are needed, which may be a long-term venture.

Further research also could include different data pooling techniques or examination of forest acreage trends on a less aggregated basis, possibly by state in order to isolate key factors underlying subregional forestland ownership strategies. Unavailability of data may preclude analyses at the state level (i.e., degrees of freedom problem), but at a minimum, aggregate studies can be augmented with descriptive studies at lower levels. One possible improvement, dependent on data availability, is the direct estimation of factors influencing changes in specific forest type acreages.

Attempts to validate long-term land use models have centered on methods of evaluating the goodness-of-fit of model simulations over historical periods. However, this is a subjective process that must consider possible future structural changes, and which involves using both economic and statistical criteria. Building confidence in the plausibility of the projections depends to some degree on logical extrapolations of empirical evidence, which is often limited in its extent and quality. Conventional statistical measures of uncertainty can only provide the basis for establishing an upper bound on the accuracy of projections. Validation in part rests on judgments based on historical data and perceptions formed by experiences related to the relationship of past to future populations under study. Although no definitive conclusions based on statistical theory can be drawn from this analysis, the model appears to be reasonable. As a proxy for reality, a model's behavior is evaluated to provide insight into analyzing economic issues. A more practical test of validity is to use the SAM model in an actual forecasting environment, with attention given to ranges of forecasts and the robustness of the model.

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Appendix

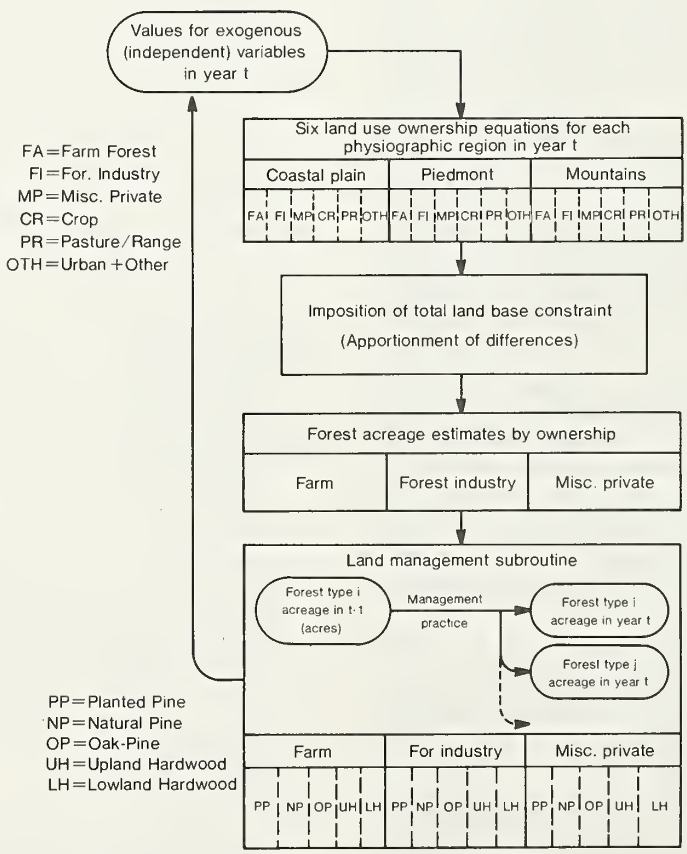

Figure 1A. Overall schematic of the Southeast Area Model.

GPO 846-603

Alig, Ralph J. 1984. Modeling acreage changes in forest ownerships and cover types in the Southeast. USDA Forest Service Research Paper RM-260, 14 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

A system based on economic criteria projects change in acreages of six major land ownerships/uses by physiographic region in the Southeast, including three private forest ownership classes. Acreage changes for five major forest types, on each of the three forest ownerships, are projected using transition rates among forest types associated with the application of certain management practices. Changes in forest acreage, projected by decade to the year 2040, indicate a continued drop in farm forest acreage and natural pine acreage.

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U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

Rocky Mountains

Southwest

Great Plains

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

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Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

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*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526